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THE **BOEING** COMPANY
**AERO-SPACE DIVISION**
**SATURN BOOSTER BRANCH**

DOCUMENT NO. T5-6539-99

VOLUME ______ OF ______

TITLE METALLURGICAL ANALYSIS OF BACB30GZ8 FASTENER FAILURES, 504 VEHICLE FUEL TANK

MODEL NO. Saturn V/S-IC CONTRACT NO. NAS 8-5608

ISSUE NO. M-23 ISSUED TO R. L. Murphy

| | | | |
|---|---|---|---|
| PREPARED BY | C. B. Schwartz<br>C. B. Schwartz | 5-7996 | 10/17/67 |
| SUPERVISED BY CBS | E. L. Clark<br>E. L. Clark | 5-7996 | 10/18/67 |
| APPROVED BY | W W Davis<br>W. W. Davis | 5-7900 | 10/20/67 |
| APPROVED BY | | | |
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S-406-35-11 ORIG. 1/64

## ABSTRACT

Unplanned Event Records U272346, July 15, 1967 and U272353 July 16, 1967 reported a total of eleven fastener fragments discovered during the post static firing inspection of the 504 Vehicle Fuel Tank. These fragments were identified as being from seven fasteners. All failures were found to be caused by stress corrosion. The recommendations of T5-6539-93, "Metallurgical Analysis of a BACB30GZ8-6 Fastener Failure, 503 Vehicle Fuel Tank " should be followed, i.e., remove unfavorable grain pattern to raise the stress corrosion threshold, or use a collar which induces a preload below the existing stress corrosion threshold.

## KEY WORDS

Stress corrosion cracking

Aluminum alloy fasteners

BACB30GZ

BACC30P

7075-T6

Recrystallization

TABLE OF CONTENTS

## LIST OF FIGURES

1.0 OBJECT

The object of this study was to determine the cause of failure of seven BACB30GZ8 fasteners in the 504 vehicle fuel tank.

2.0 BACKGROUND

The discovery of nine fragments of BACB30GZ8 fasteners in the 504 vehicle fuel tank was reported in Unplanned Event Record U272346 July 15, 1967. These fragments consisted of four shanks fractured at the threads, and five BACC30P8 collars containing threaded portions of BACB30GZ8 fasteners. Three pairs of fragments were mated indicating that six fasteners failed. Unplanned Event Record U272355 July 16, 1967 reported the discovery of one BACB30GZ8 fastener head and the remainder of the fastener in the 504 vehicle fuel tank. In total four whole and three partial BACB30GZ8 fasteners were discovered failed in post static firing checkout of the 504 vehicle fuel tank.

Failure of this type fastener was reported in T5-6539-93. This report analyzed the stress corrosion failure of a BACB30GZ8-6 fastener from the 503 vehicle fuel tank; and analyzed the susceptibility of this type fastener to stress corrosion cracking. Figure 1 shows the specification control drawing for BACB30GZ, which is a 7075-T6 aluminum alloy hex-drive protruding shear head bolt. The five identifiable bolts were all BACB30GZ8-6, manufactured by the Hi-Shear Corporation. All six BACC30P8 collars were manufactured by the Voi-Shan Manufacturing Company. Test Report T5-6539-93 concluded that stress corrosion cracking was caused by a partial recrystallization of metal during heat treatment, which had lowered the expected stress corrosion threshold of the bolt to a level exceeded by the preload induced by the collar.

3.0 CONCLUSION

It is concluded that seven BACB30GZ8 fasteners from the 504 vehicle fuel tank failed by stress corrosion cracking which initiated at areas of recrystallization.

4.0 RECOMMENDATIONS

It is recommended that these fasteners be manufactured as stated in T5-6539-93, i.e., to remove the unfavorable recrystallized grain in the threads and in the head. This can be accomplished by doing all forming after solution heat treatment. An alternate solution would be the use of BACC30PR collars which induce lower preloads.

5.0 PROCEDURES AND RESULTS

5.1 The cause of failure of seven BACB30GZ fasteners was analyzed using fractography, metallography, hardness testing and conductivity measurements. Fracture faces were examined at high and low magnifications to identify the type of failures. Microscopic examination determined the fracture mode and whether any irregularities existed in the microstructure of the material. The temper of the alloy was determined using hardness and conductivity measurements.

5.2 Upon receipt in the laboratory the eleven fastener fragments were identified and mated where possible. Three threaded fragments were mated with three remaining portions of fasteners. One head was mated with a shank. Three fragments were unmated consisting of one fastener fractured at the second thread and two threaded fragments. Five fasteners were identified as being manufactured by Hi-Shear Corporation. The six collars were identified as being manufactured by Voi-Shan Manufacturing Company. Each fastener was given an arbitrary identification number before analysis was begun.

Fractographic study at 7X to 30X using a wide field stereoscope revealed fracture surfaces typical of stress corrosion cracking in fasteners of this type. Figures 2 - 7 are fractographs of each specimen showing a distended surface characteristic of the expansion associated with corrosion in aluminum alloys. Microscopic study of metallographic specimens at 100X and 500X revealed all fractures to be intergranular, with secondary intergranular cracking. This type of fracture mode and crack pattern is typical of stress corrosion cracking in 7075-T6 aluminum alloy. Figures 8 - 13 show the results of microscopic examination. It was noted in specimen number four, shown in figure eleven that although failure was in the head to shank transition stress corrosion cracking was also observed in the thread region.

Hardness readings and conductivity tests confirmed the temper to be T6. The average hardness of four specimens was Rockwell B 85 while the average conductivity of five specimens was 31.5% IACS.

5.3 Stress corrosion is produced by the interaction of sustained tensile stress and a corrosion reaction. In all cases failure and cracking occurred at regions where manufacturing had produced a recrystallized grain structure and where there was a stress concentration. The raising of the stress corrosion threshold by the elimination of recrystallized grain structure or the reduction of stress concentrations, by the lowering of preload, will reduce the possibility of failure.

## 6.0 REFERENCES

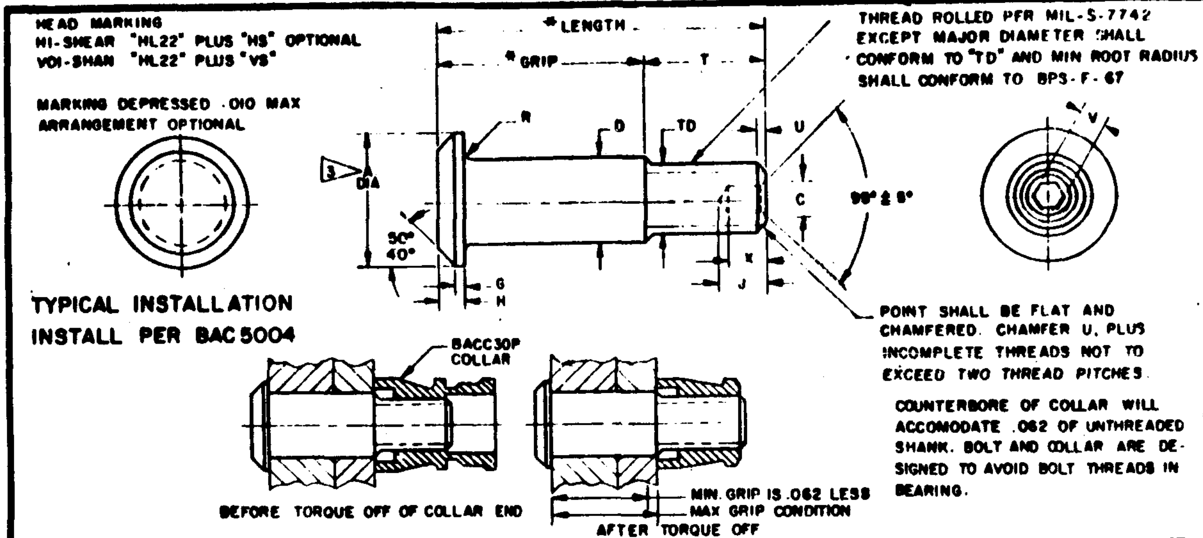
Test Report: T5-6539-93, "Metallurgical Analysis of a BACB30GZ8-6 Fastener Failure, 503 Vehicle Fuel Tank."

Unplanned Event Record U272346, July 15, 1967

Unplanned Event Record U272355, July 16, 1967

BACB30GZ

BACC30P




| BOEING STANDARD NUMBER BACB30GZ | SUPPLIER PART NO. HI-SHEAR VOI-SHAN HL22 | | NOM THREAD SIZE | A DIA | C DIA | D DIA | E 3 | G REF. | H | J MAX | R RAD | T REF | TD | U REF | V HEX | X MIN | Y 3 | Z 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5-* 1 | -5-* | | 8-32 UNC-3A | .262 .242 | 2 | .1635 .1625 | .010 | .020 | .055 .045 | .178 | .025 .015 | .312 | .1595 .1570 | .031 | .0645 .0635 | .115 | .0045 | .0040 |
| 6-* | -6-* | | 10-32 UNF-3A | .315 .295 | .119 .104 | .1895 .1885 | .010 | .025 | .065 .055 | .178 | .025 .015 | .325 | .1840 .1810 | .031 | .0806 .0791 | .115 | .0045 | .0040 |
| 8-* | -8-* | | 1/4-28 UNF-3A | .412 .387 | .142 .122 | .2495 .2485 | .010 | .030 | .090 .080 | .200 | .025 .015 | .395 | .2440 .2410 | .031 | .0967 .0947 | .130 | .0045 | .0030 |
| 10-* | -10-* | | 5/16-24 UNF-3A | .505 .475 | .180 .160 | .3120 .3110 | .012 | .035 | .110 .100 | .240 | .030 .020 | .500 | .3060 .3020 | .047 | .1295 .1270 | .150 | .0045 | .0030 |
| 12-* | -12-* | | 3/8-24 UNF-3A | .600 .565 | .217 .197 | .3745 .3735 | .014 | .040 | .135 .125 | .275 | .030 .020 | .545 | .3680 .3640 | .047 | .1617 .1582 | .180 | .0060 | .0025 |

* - GRIP DASH NO. IN 16THS. SEE BACB30PM, SHEET 2 (PAGE 80.85.6.1.2) FOR GRIP AND LENGTH DIMENSIONS.

1 -5 INACTIVE FOR DESIGN AND PROCUREMENT AFTER 1 OCT 65. BACB30OP5 LOCKBOLTS (SAME GRIP DASH NUMBER) ARE OPTIONAL FOR ALL USE. INSTALL LOCKBOLTS WITH NAS1080D5 COLLAR PER BAC 5004.

2 EVIDENCE OF BROKEN EDGE ACROSS POINTS -5 ONLY.

3 CONCENTRICITY: HEXAGON SOCKET TO THREAD PITCH DIA. WITHIN E VALUES TIR.
A TO D DIAMETERS WITHIN .010 TIR.
THREAD PITCH DIA. TO D DIA. WITHIN Y VALUES TIR.

4 SHANK STRAIGHTNESS: WITHIN Z VALUES TIR PER INCH OF LENGTH.

MATERIAL: 7075-T6 ALUMINUM ALLOY PER QQ-A-225/9 OR QQ-A-430. D

HEAT TREAT: MIL-H-6088 (SHEAR AND TENSILE STRENGTH PER PROCUREMENT SPECIFICATION).

FINISH: ANODIZE PER MIL-A-8625. COLOR NATURAL.

LUBRICATION: LAURIC ACID OR CETYL ALCOHOL (SEE PROCUREMENT SPECIFICATION).

SURFACE TEXTURE: (AA MAX. PER ASA B46.1) HEAD TO SHANK FILLET, THREAD ROOT, THREAD FLANKS, AND SHANK, 32; BEARING SURFACE OF HEAD, 63; OTHER SURFACES, 125.

PROCUREMENT SPECIFICATION: BPS-F-67 (PAGE 680.85.6.1).

PROCUREMENT: HI-SHEAR CORPORATION, 2600 WEST 247TH. STREET, TORRANCE, CALIFORNIA. CODE IDENT. NO. 73197

VOI-SHAN MANUFACTURING COMPANY, 8463 HIGUERA STREET, CULVER CITY, CALIFORNIA. CODE IDENT. NO. 92215

THE SUPPLIERS LISTED AND THEIR AUTHORIZED DISTRIBUTORS ARE THE ONLY APPROVED SOURCES FOR THE ABOVE QUALIFIED PRODUCTS. CHANGES IN PRODUCT DESIGN WITHOUT PRIOR BOEING APPROVAL MAY RESULT IN SUPPLIER DISQUALIFICATION. SUPPLIERS OF COMPETITIVE PRODUCTS MAY APPLY TO A MATERIEL DEPARTMENT OF THE BOEING COMPANY FOR QUALIFICATION.

USAGE AND APPLICATION INFORMATION

USE BACB30GZ BOLTS WITH BACC30P (PAGE 80.85.6.16) COLLARS.

WHERE STRENGTH REQUIREMENTS ARE LOW, THE BOLTS MAY BE USED TO REPLACE STEEL SHEAR FASTENERS FOR WEIGHT SAVING PURPOSES.

CODE: FIRST DASH NUMBER INDICATES NOMINAL DIAMETER IN 32NDS. SECOND DASH NUMBER INDICATES MAXIMUM GRIP IN 16THS.

EXAMPLE: BACB30GZ8-12 = BOLT, PROTRUDING SHEAR HEAD, ALUMINUM ALLOY 1/4 (8/32) NOM. DIA., 3/4 (12/16) MAX. GRIP.

RIVET CODE: BACB30GZ BOLT WITH BACC30P COLLAR = XGH.

SEE PREFACE FOR GENERAL USAGE NOTES.

REV. Ⓐ 5 JUL 62, Ⓑ 4 SEP 62, Ⓒ 26 MAY 66 Ⓓ 13 SEP 66

DATE 12 FEB 62

CODE IDENT NO. 81205

BAC B30GZ

# BOLT, PROTRUDING SHEAR HEAD
## ALUMINUM ALLOY, HEX-DRIVE

BAC B30GZ

BOEING STANDARD

SPECIFICATION CONTROL DRAWING



PAGE 80.85.6.7

FIGURE 1 - Specification Control Drawing BACB30GZ

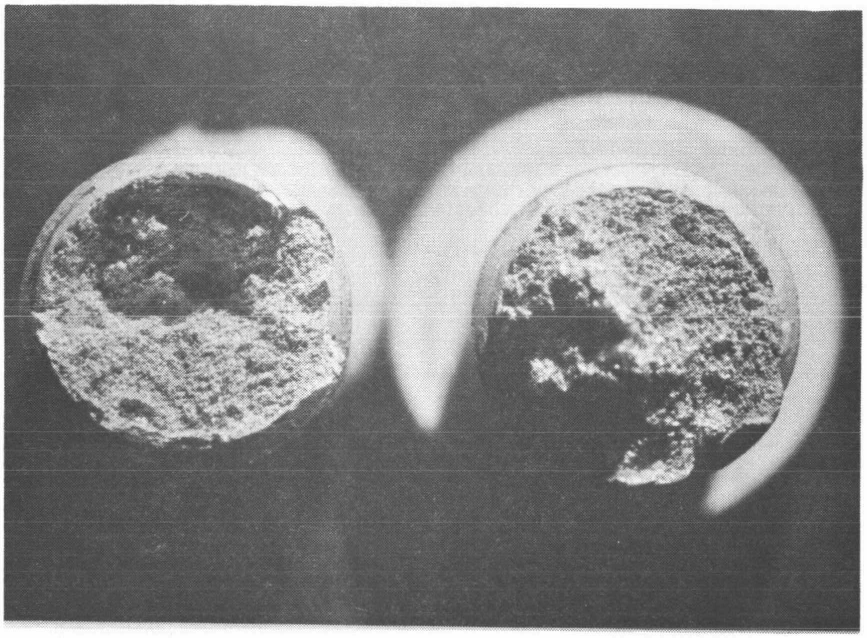


FIGURE 2 - FRACTURE SURFACES, SPECIMEN 1, 8X

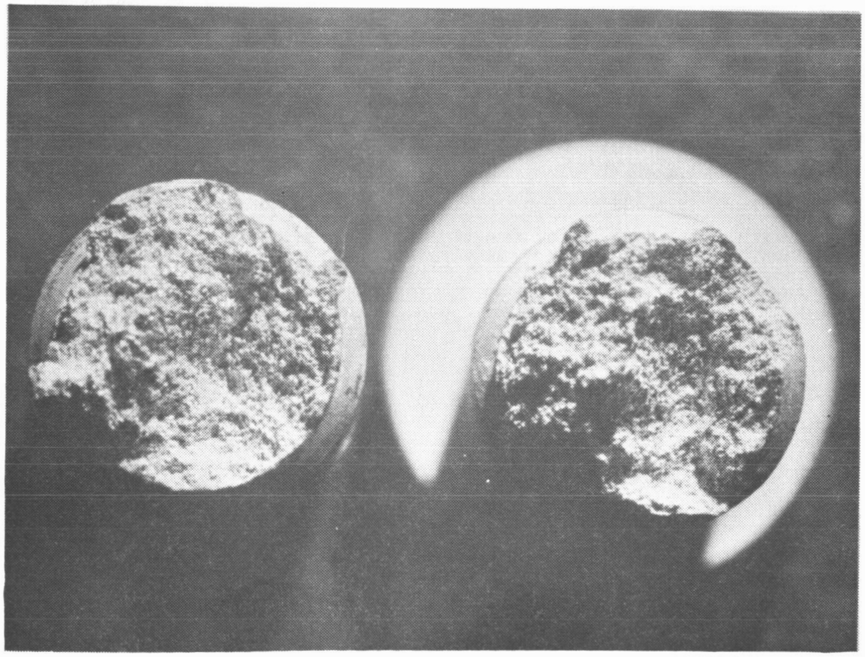


FIGURE 3 - FRACTURE SURFACES, SPECIMEN 2, 8X

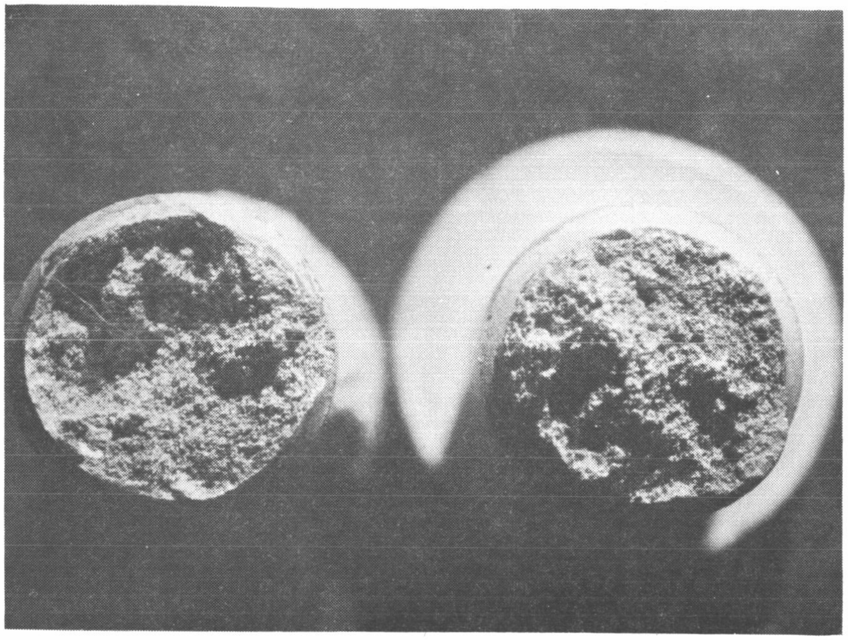


FIGURE 4 - FRACTURE SURFACES, SPECIMEN 3, 8X

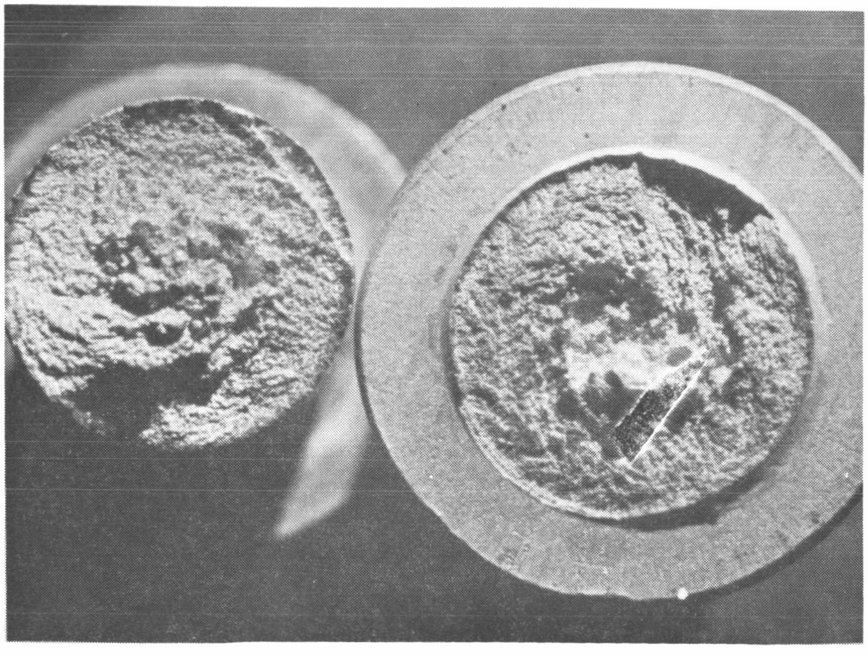


FIGURE 5 - FIGURE SURFACES, SPECIMEN 5, 8X

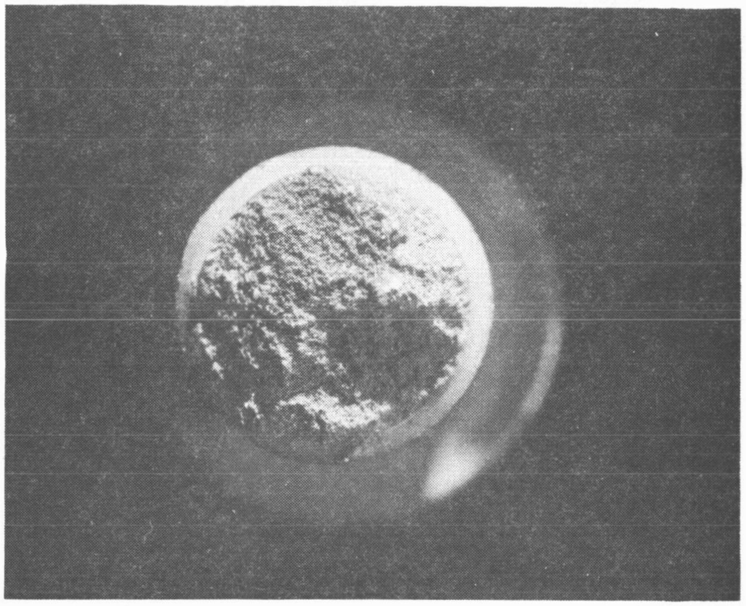


FIGURE 6 - FRACTURE SURFAEE, SPECIMEN 5, 8X

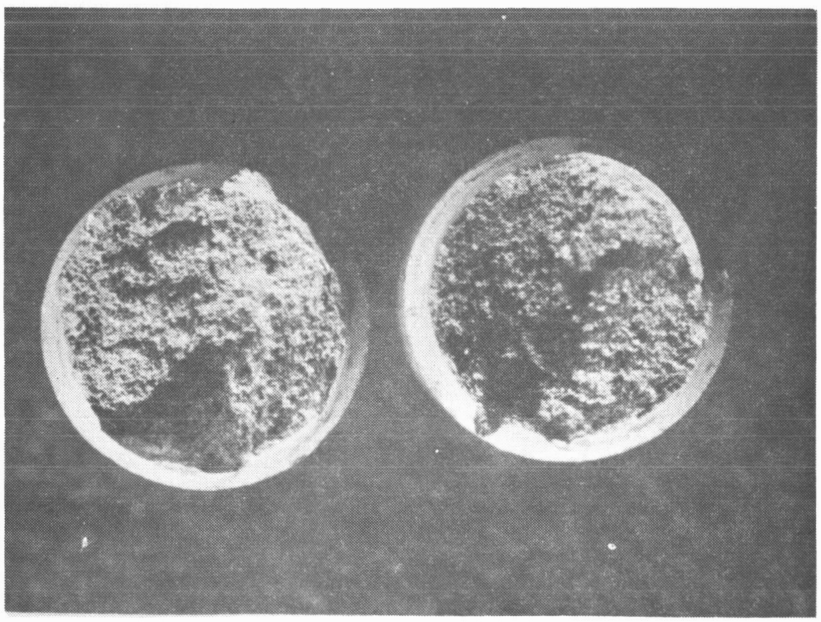
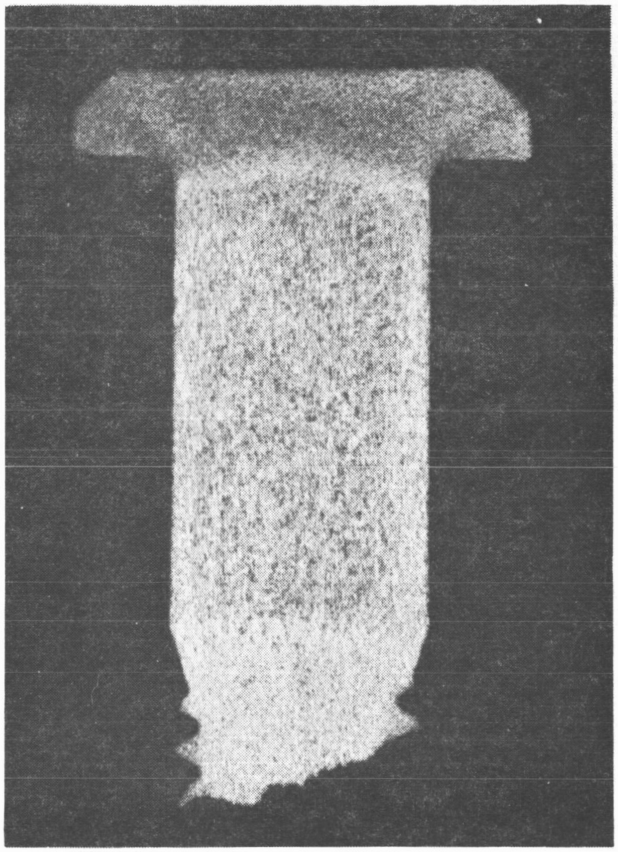
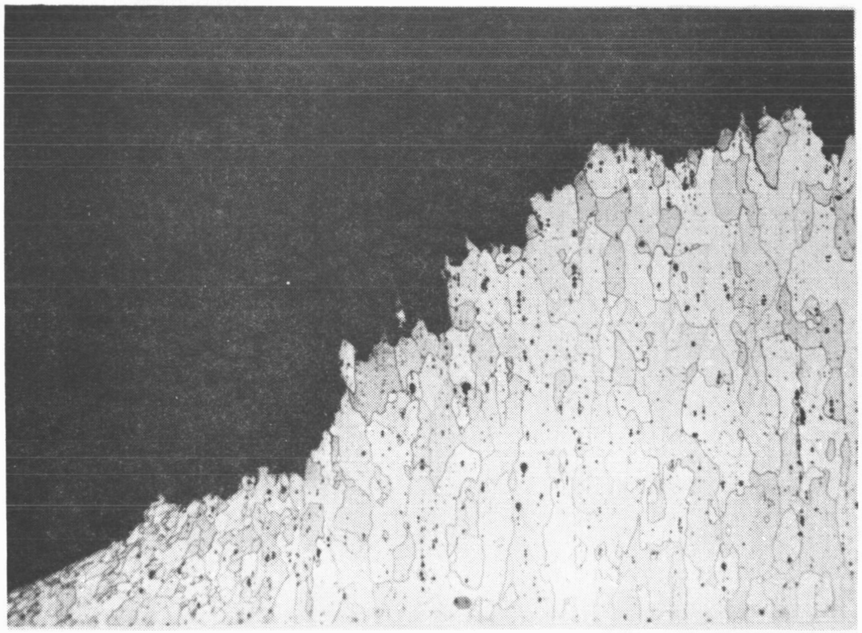


FIGURE 7 - FRACTURE SURFACE, SPECIMENS 6 and 7, 8X

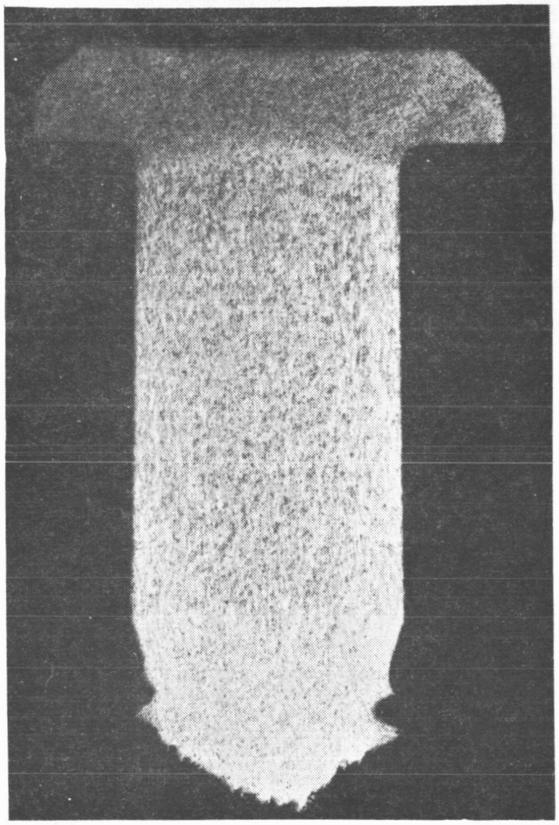


A - 6X, KELLER'S ETCH

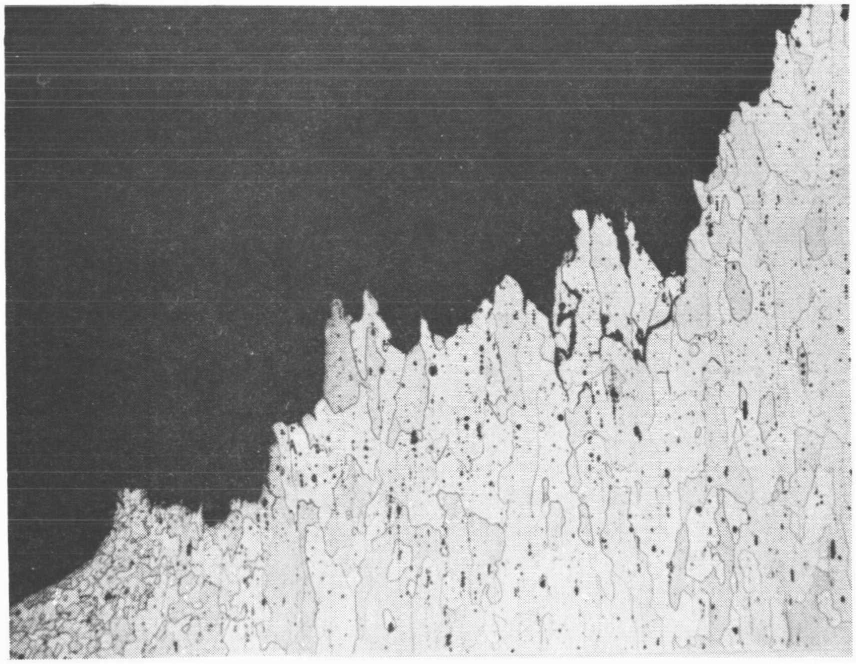


B - 100X, KELLER'S ETCH

FIGURE 8 - MICROSTRUCTURE, SPECIMEN 1

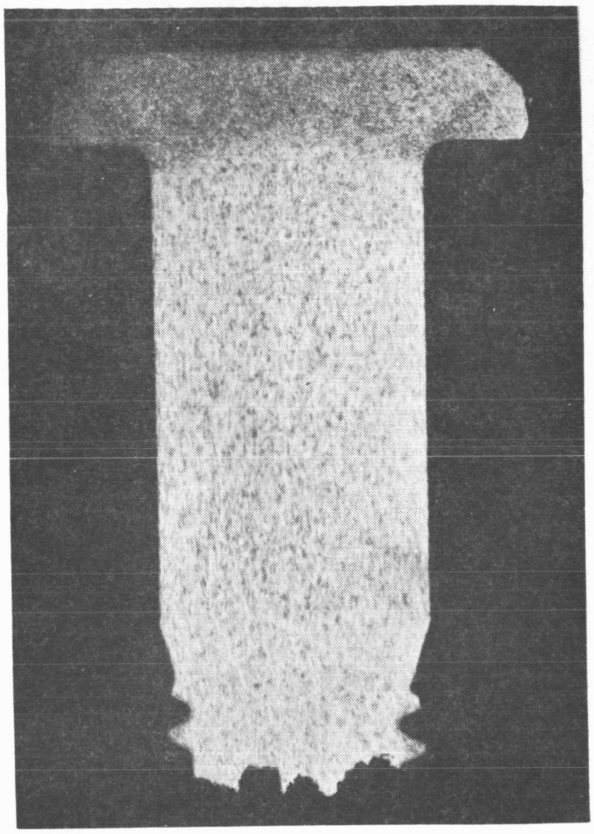


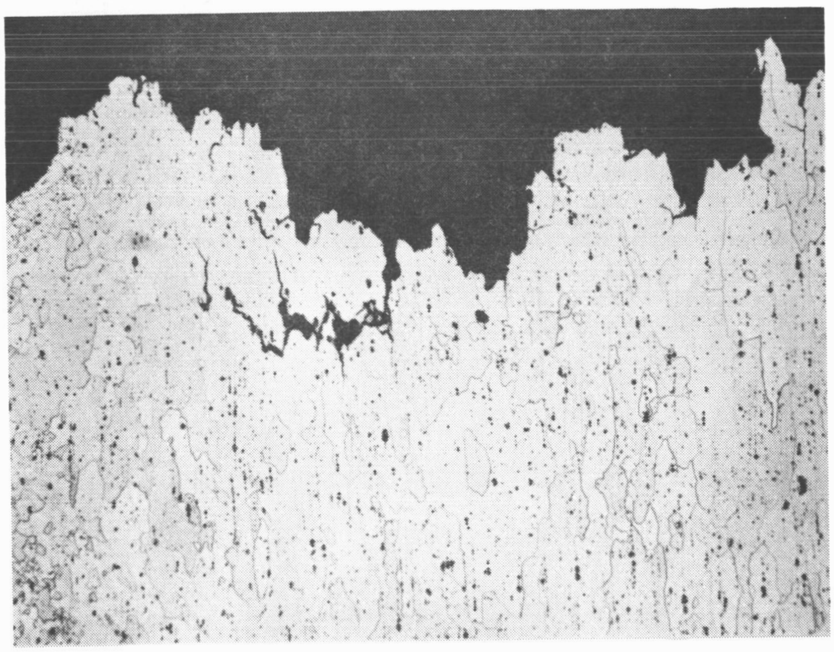
A-6X, KELLER'S ETCH



B - 100X, KELLER'S ETCH

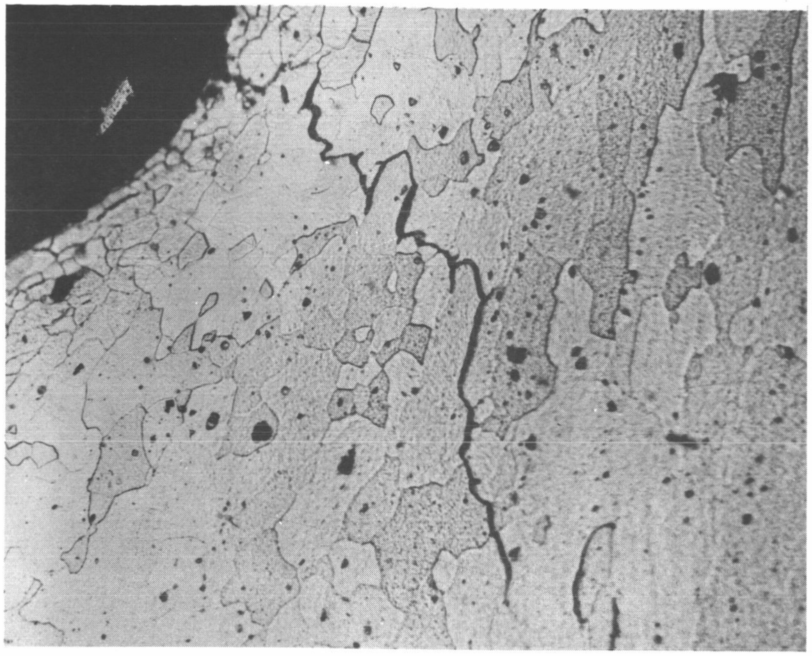
FIGURE 9 - MICROSTRUCTURE, SPECIMEN 2



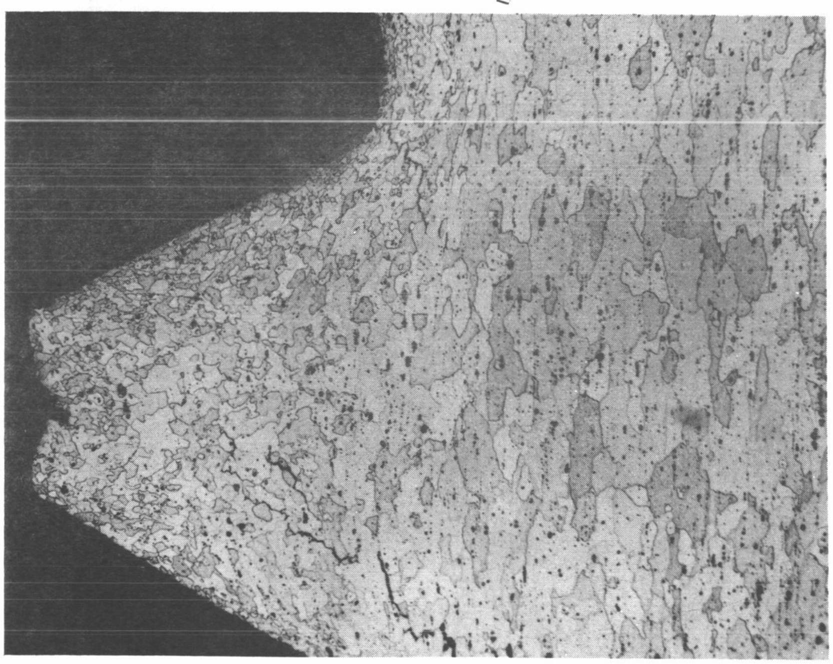


B - 100X, Keller's Etch

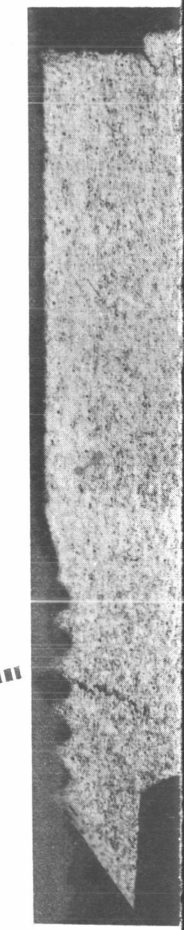
FIGURE 10 - MICROSTRUCTURE, SPECIMEN 3



C - 500X, Keller's Etch

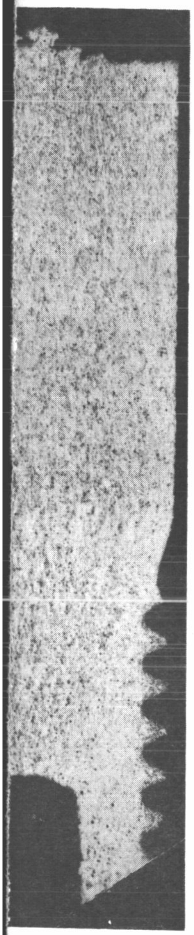


B - 100X, Keller's Etch

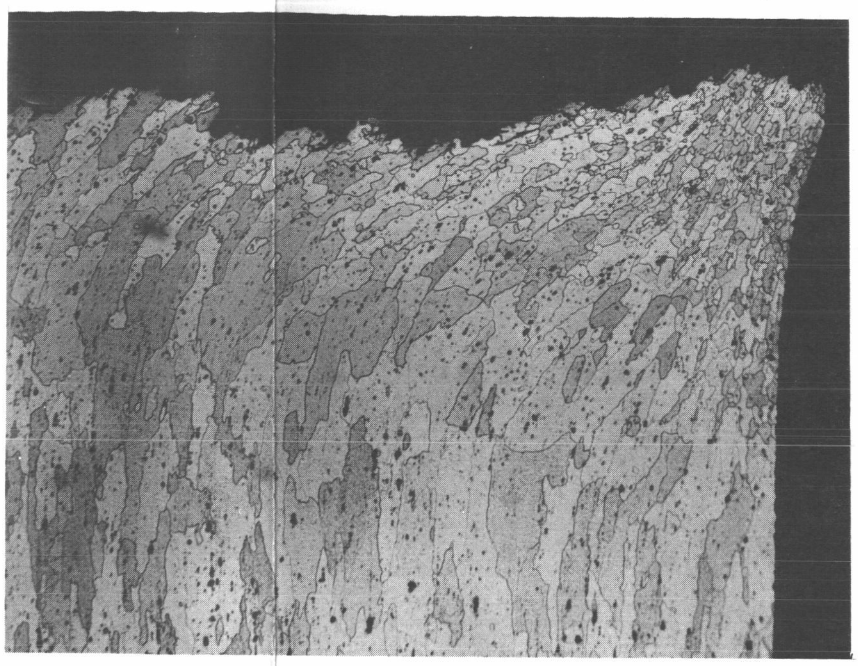


A - 6X, Ke

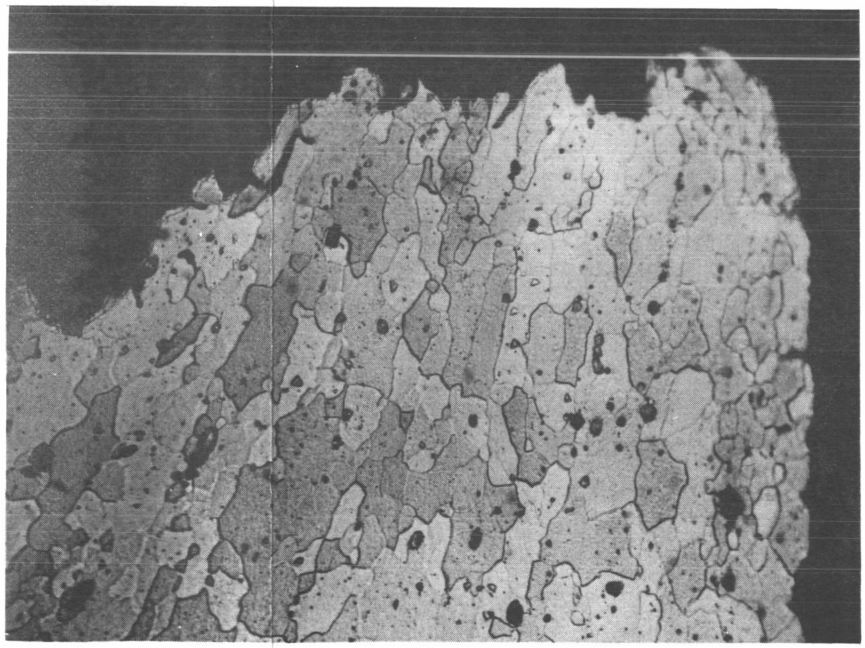
FIGURE 11 - Microstruc



ller's Etch

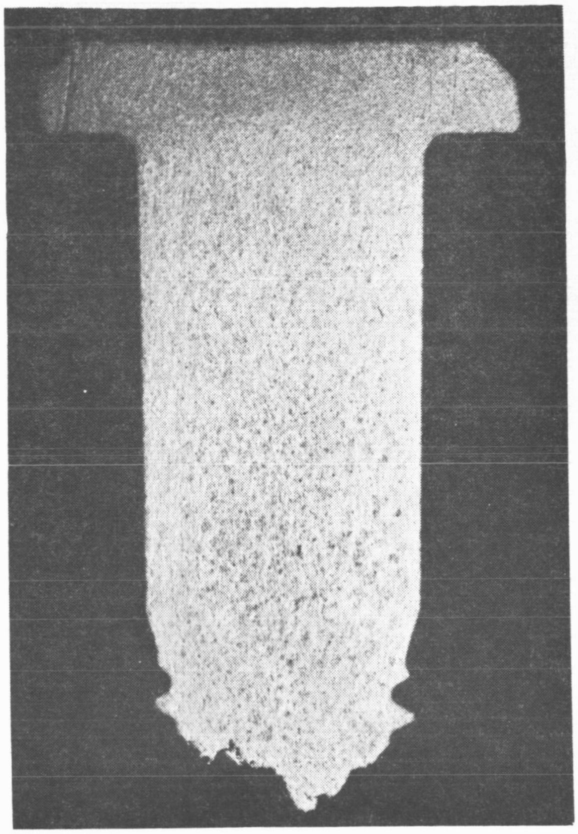


D - 100X, Keller's Etch

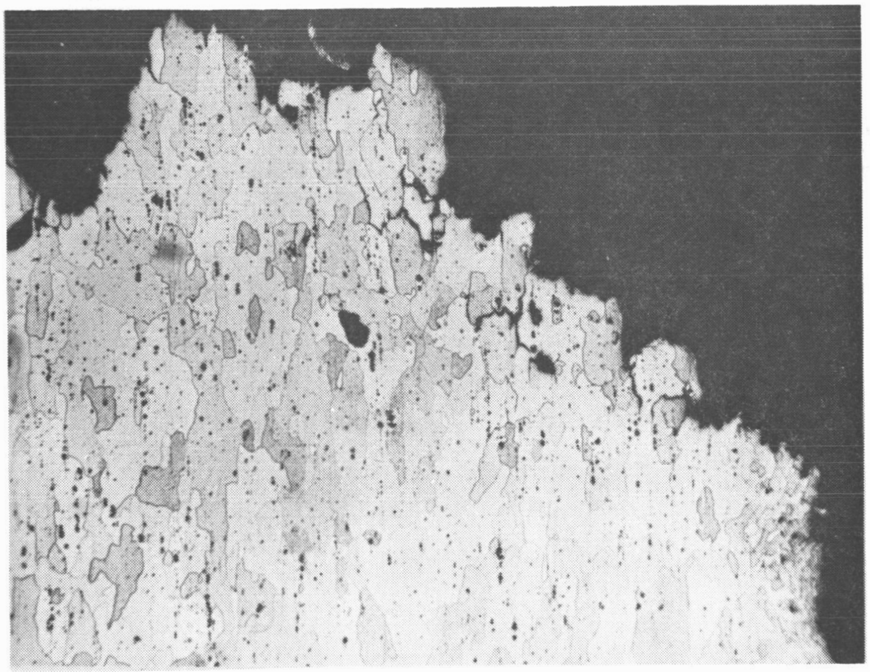


E - 500X, Keller's Etch

ture, specimen 4.

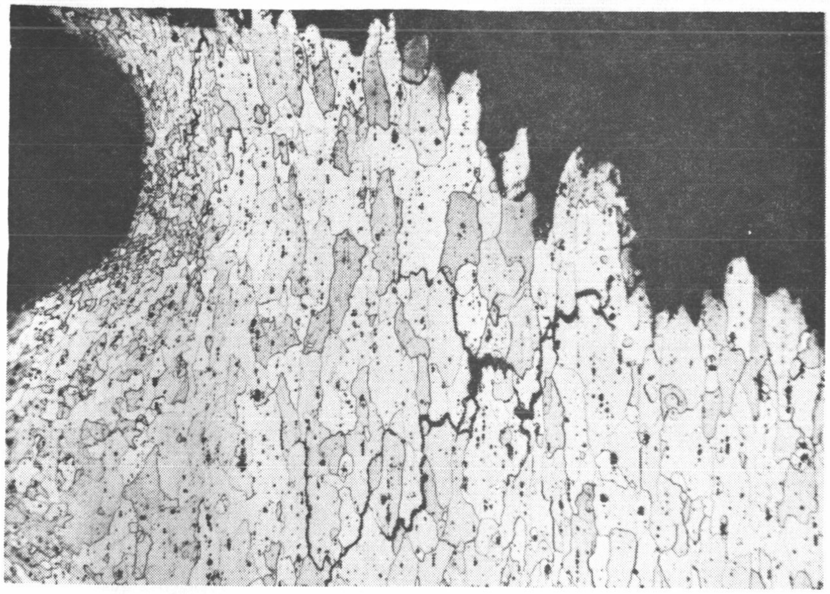


A - 6X, KELLER"S ETCH

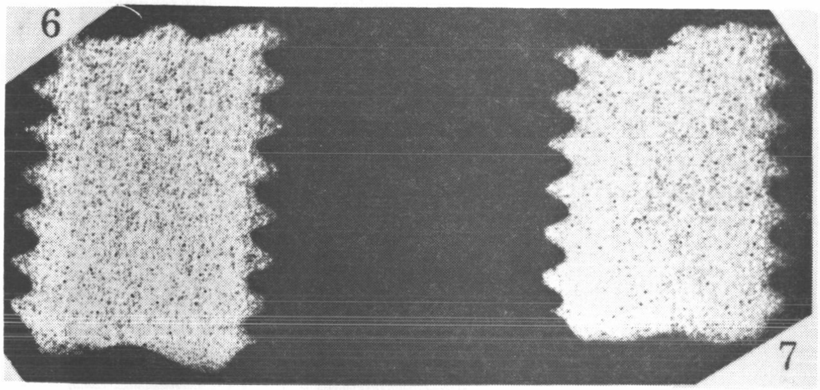


B - 100X, KELLER'S ETCH

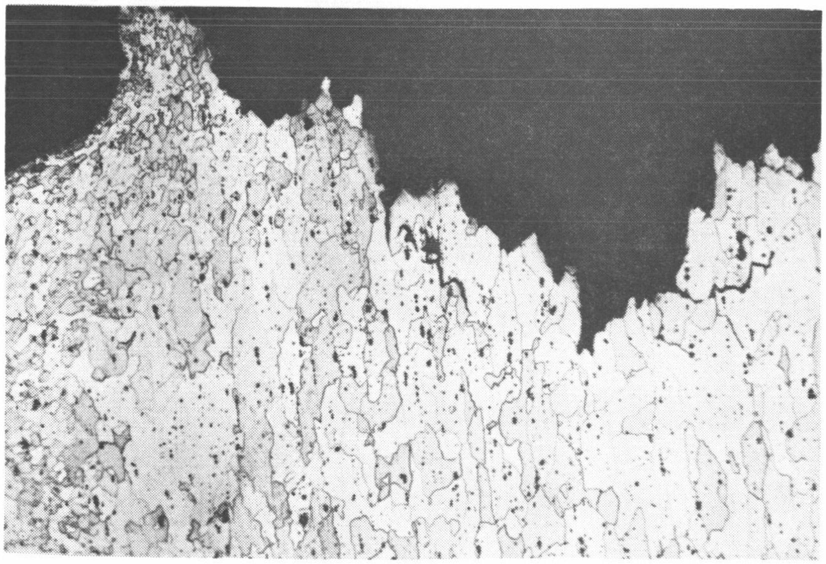
FIGURE 12, MICROSTRUCUTRE, SPECIMEN 5



A - SPECIMEN 6, 100X, KELLER'S ETCH




B - SPECIMENS 6 and 7, 6X, KELLER'S ETCH



C - SPECIMEN 7, 100X, KELLER'S ETCH